Modeling 6G Software Business Ecosystem: A Look Ahead

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Abstract

The 6G technology is under development and is expected to be realized by 2030. How to commercialize 6G needs to be considered from a business perspective before technology matures. Understanding the 6G software business ecosystem offers valuable insight into the opportunities and challenges that stakeholders can grasp or overcome. As an open and Software-Defined Network (SDN), 6G business is highly software-intensive, which shifts the previous linear value chains to the future complex value networks. However, existing 6G research mainly focuses on technology standardization and network orchestration, lacking sufficient discussion from the software-intensive business perspective. To address this gap, this study aims to model the 6G software business ecosystem, by adopting methodologies from the Future Studies field, primarily Morphological Analysis (MA). Meanwhile, we follow the five-stage business ecosystem modeling approach as the guideline for decomposing the 6G software business ecosystem into key building blocks. This study identifies four building blocks, namely the 6G vision, stakeholders, their complex relationships, and key opportunities and challenges. Each building block is precisely depicted, moreover, the complex roles and dynamic relationships between stakeholders from software-intensive industries are highlighted.

CCS Concepts: • **Software and its engineering** → **Entity relationship modeling**; • **General and reference** → *Surveys and overviews*; • **Computing methodologies** → **Modeling methodologies**.

Keywords: 6G, software ecosystem, business ecosystem, Morphological Analysis, business ecosystem modeling

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1 Introduction

The revolutionary advancements have been witnessed during the transition from 2G to 5G while the novel telecommunication infrastructure improvements dramatically impact everyone's daily life and global business industry. Currently, we are in the early research stage of 6G. The 6G communication standardization is under development and is expected to be commercialized in 2030 [8]. This coming generation of new communication technologies not only improves the network speed, latency, capacity, and connectivity but also offers a huge number of opportunities for business innovation. As an open, flexible, and programmable [29] [7] Software-Defined Network (SDN), the 6G business is highly software-intensive [28]. The previous linear value chains in the traditional telecommunication industry are shifted to complex value networks in the SDN 6G [28]. In these value networks, the stakeholders' and participants' success and thrive highly depend on the health and sustainability of the 6G software business ecosystem [18]. The business perspective consistently holds a significant role in comprehending the opportunities that new technology could provide for stakeholders [4]. However, our SLR research found that most existing research related to 6G focuses on the technology perspective and lacks sufficient business consideration.

Continuing the vision of the 5G business, 6G is expected to shape different wireless communication services and software businesses, novel business models, as well as respective ecosystems [3]. While 5G has been regarded as a connectivity platform [3], 6G will extend the connectivity towards data platforms, connecting intelligence and services [36]. 6G is designed to connect everyone, everything, everywhere and the 6G ecosystems are extremely complex and multi-dimensions. In order to help the companies from the software-intensive industry better understand 6G macro opportunities and challenges, as well as micro stakeholder roles, our study aims to model the 6G ecosystem by its main components, which are also called building blocks. Decomposing 6G software

business ecosystems into blocks provides theoretical contributions for industrial stakeholders as well as governmental organizations in their decision-making process.

This paper is structured as follows: Section 2 introduces the related concepts of the 6G software business ecosystem, including the software ecosystem and business ecosystem. In Section 3, the adopted methodologies from Foresight Diamond and rationale are presented. Section 4 explains how the 6G software business ecosystem is decomposed into building blocks and illustrates the four building blocks in detail. Finally, this paper concludes the findings while modeling the 6G software business ecosystem as well as future work.

2 Background

The 6G ecosystem is actually a software ecosystem due to the SDN nature of 6G technology. Open Networking Foundation [1] defined SDN in the white paper as: "An emerging network architecture where network control is decoupled from forwarding and is directly programmable." The software offers 6G more flexibility and programmability to support users' requirements for the coming ultra-speed network generation, which distinguishes 6G from previous generations of networks. Since 6G is SDN and software plays a significant role in the 6G ecosystem, we concretize the concept of the 6G ecosystem to the 6G software ecosystem.

Following is an explanation of using the term 6G software business ecosystem instead of 6G software ecosystem. A business ecosystem is a novel type of value system [16], and James F. Moore is one of the first scholars who introduced the term "business ecosystem". In his paper on Harvard Business Review, it is said [27]:

"*The birth of business ecosystems bet on a seed innovation that can lead to revolutionary products, discover the right customer value proposition, and design a business that can serve the potential market*".

Business transformation and innovation are vital for 6G to become a real General-Purpose Technology (GPT). A general purpose technology (GPT) is a pervasive technology [9] that can be widely applied in various industrial fields. Three key characteristics of GPTs are shown below, which can be regarded as the criteria for examining whether a technology can be a GPT or not: *(i)* GPTs are pervasive and have a long lifespan [46], *(ii)* GPTs are usually adopted in a wide scope of industry sectors and enable the innova-tional complementarities across different sectors [9], [23], and *(iii)* GPTs own dynamism for continuous technical innovation and improvements [9], [15]. Since the last generation, 5G has been considered to be a junior GPT [25], and 6G owns a large chance to become a real GPT. A GPT must meet the following three features: *(i)* enduring and widespread, *(ii)* potential for innovation in various industries, and *(iii)* driving ongoing technical advancements [9]. Widely and continuous innovation in business will highly contribute to 6G being a GPT. Thus, by modeling the 6G software business ecosystem, we emphasize the driven role of business during the 6G software ecosystem forming and developing process.

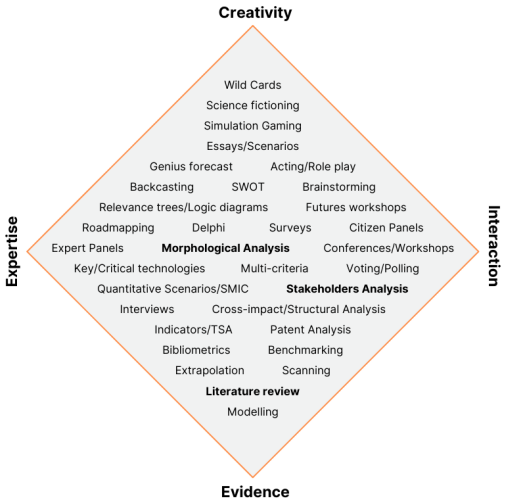

Figure 1. Foresight Diamond

3 Research Approach

Since 6G technology is still under development and no real software business practices are available for empirical research, 6G-related topics are strongly related to the Future Studies field. This field is extremely interdisciplinary and has its methodologies called Foresight Diamond [32], which is a widely adopted framework [37] for understanding and selecting the rich methods in foresight studies, as shown in Figure 1.

Morphological Analysis (MA) is in the central position of the Foresight Diamond figure, and it is an approach for structuring problems rather than solving them [40] [41]. It is the first reason that we adopted MA as the main research approach - we are currently in the beginning stage of this 6G business research, and it is crucial to break down the complex context into manageable pieces of problems. Secondly, MA bridges between the foresight and planning of the 6G software business ecosystem [32]. Last, MA offers the possibility of being mixed with other Foresight methodologies [32]. In this paper, the other two approaches, literature review and stakeholder analysis from the Foresight Diamond, are involved when understanding certain building blocks. The literature review is used to explore the trends of 6G [32], while the stakeholder analysis is adopted for involving industrial participatory in our future work.

MA was originally used in the biology field to study how organism forms [33]. No systematic guidelines are available for applying MA in the software engineering area. In this paper, we basically follow the Yoon [41]'s instructions. As Yoon said MA can never stand on its own and needs to be

complemented with other methods [41]. Thus, we also take the five-stage business ecosystem architecture design approach [24] as the main guideline when decomposing the 6G software business ecosystem into building blocks. This business ecosystem modeling approach consists of five stages: *(i)* Boundary identification of a business ecosystem, *(ii)* Identification of actors and their roles in the business ecosystem, *(iii)* Identification of actors' value propositions, *(iv)* Identification of interaction between actors, and (v) Verification of business ecosystem architecture design [24]. In our study, 6G software sets the boundary of this business ecosystem. To fulfill the whole business ecosystem modeling procedure, the roles and their potential interactions will be identified as building blocks of the 6G software business ecosystem in the following section.

4 6G Software Business Ecosystem Building Blocks

As a normative approach [41], our MA instance starts with identifying future user needs as well as society's expectations, then ultimately leads to developing software solutions to meet these requirements. Before identifying the building blocks, we conducted a Systematic Literature Review (SLR) to understand the 6G ecosystem, especially the 6G visions and key opportunities and challenges. Also, by following the methodologies from Foresight Diamond and the five-stage business ecosystem architecture design approach mentioned in section 3, we determine four building blocks for modeling the 6G software business ecosystem, shown in Figure 2.

4.1 6G Vision

After conducting the SLR work, we found that the existing 6G visions are comprehensive, multi-perspective, multi-level, and multi-stakeholder [2]. Some of them take 6G technical parameters as 6G visions, such as visions in [43] and [21]. While many visions are generated based on specific use cases which need to be understood under certain contexts and is difficult to summarize them into one sentence, like [46], [38], and [44]. Until now, there has not been a software business-oriented description of the 6G vision, although 6G is expected to bring a profound and transformative business revolution, surpassing changes brought by any previous generations.

The findings from SLR work show that Artificial Intelligence (AI) is one of the key enabling technologies, as mentioned in the paper [39], [45], [14], [46], and [4]. 6G is indeed AI-driven modern technology also for the reason that AI will be everywhere from now on and soon [46], [14], [39], [45], and [6]. Besides leading breakthrough innovations in terms of 6G network slicing, edge computing, massive data management, and security solutions, from the software business perspective, AI offers new approaches to software design which bring superior performance and user experiences [44] AI elevates 6G into an intelligent space [30] by connecting everything through the ultra-speed network. 6G transfers the business scenarios from the 5G Internet-of-Things paradigm to a broader concept of Internet-of-Everything. The term everything can be further elucidated as various forms of users' intelligence in the physical, digital, and virtual worlds.

In light of the existing presence of 6G visions and recognizing its potential to bring new business models and transformation [20], we provide a 6G vision viewed through the lens of software business as a bridge from 6G technology to business vision:

With an understanding of context-based communication needs, an AI-driven 6G software business ecosystem will attract novel roles and connect businesses to the digital and virtual world through sustainable business models.

This 6G software business vision is the starting point of MA process as the first and foundational building block.

4.2 6G Stakeholders, Actors, and Roles

Unlike other digital ecosystems that own at least one focal business entity, there is no owner or orchestrator in the 6G software business ecosystem. In the previous telecommunication generations, especially before 5G, Mobile Network Operators (MNOs) occupy the central position in the telecommunication ecosystem [31]. However, in the heterogeneous 6G context, the original ecosystem with focal firms has been shifted to a sharing and decentralized one. Thus, MNOs need to shift from customized network structures to innovative business model development [25], which means that MNOs will take more roles in the value network of the 6G software business ecosystem. MNO is a typical type of stakeholder in this ecosystem, while some other research calls MNO an actor [25]. Stakeholder, actor, and role are the terms that come up a lot when studying business ecosystems, but their definition varies according to different contexts.

In this paper, we clarify the differences between the three terminologies in the 6G software business ecosystem, as well as clarify their usage scenarios. An actor exists inside the 6G Software System, which is a type of role presented by human users, external hardware, or other subjects, who interact and act only in a system. The concepts of actor and system come from the definition given in Unified Modeling Language Specification [11]. By contrast, stakeholders can act both inside this system and outside the system where in the scope of the ecosystem. Stakeholders should be individuals or organizations composed of humans. Moreover, stakeholders have the capacity to take multiple roles simultaneously whereas an actor can only fulfil one single role. It is also crucial to recognize that multiple roles of one stakeholder can change dynamically. For a visual representation of the disparities between stakeholders and actors, please refer to Figure 3.

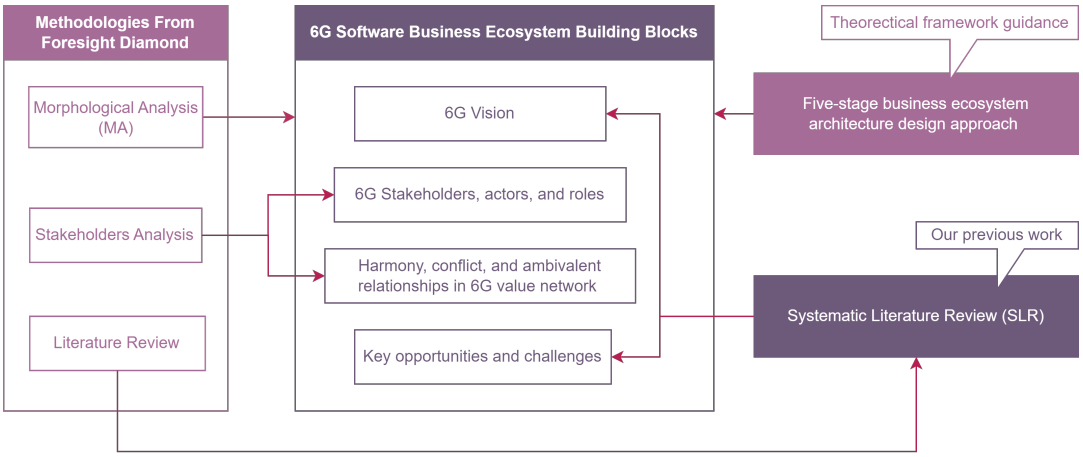

Figure 2. 6G software business ecosystem Building Blocks

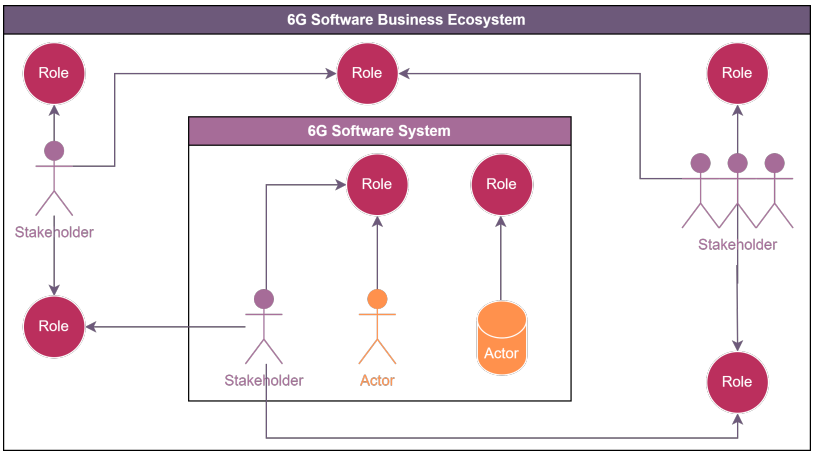

Figure 3. 6G Stakeholders, actors, and roles

4.3 Harmony, Conflict, and Ambivalent Relationships in 6G Value Network

In the context of developing the 6G software business ecosystem, it's important to recognize that stakeholders often hold multiple roles that can change dynamically. Traditional linear value chains are not adequate for describing the intricate relationships among these stakeholders. Instead, a value network approach is adopted to emphasize the interactions and flows among potentially involved stakeholders [11]. Our study conducts a mapping [5] work among various stakeholders to present the 6G software business value network, considering relationships including harmony of interests, conflict of interests, and ambivalent relationship [10].

Due to the trend of being a GPT, 6G involves more and more stakeholders while these stakeholders are shaping the 6G software business ecosystem. Besides the stakeholders from the traditional telecom industry, where MNOs belong, existing software business providers and potential cross-industry stakeholders are the three main categories of stakeholders. Examining the three stakeholder types from the traditional telecom industry, including infrastructure vendor, network operator, and software developer who provides application-level service, it is evident that they were part of the same value chain in the pre-6G generations. However, this value chain has broken down, leading to conflicts due to operators' business model transformation and the disappearance of the middleman role. In the 6G era, the market is shared, and the operators have the incentive to share their resources to enhance resource utilization in a dynamic and uncertain environment [17]. By adopting a more sharing and open business model, network operators shift away from the previous value chain, directly interacting with other stakeholders and end users. This shift can potentially lead to a competitive relationship with infrastructure vendors and software developers. Furthermore, emerging technologies

like blockchain enable 6G and intermediary roles to be eliminated [42]. Since operators can no longer act as middlemen as they did before, they need to transform themselves into either upstream or downstream segments of the value chain, which are exactly the domain of infrastructure vendors and software developers. Conflicts of interest are inevitable between stakeholders in the traditional telecom industry. Another significant conflict emerges between network operators and tech giants, as mega companies like Amazon and Google have entered the mobile wireless industry by acquiring specific frequency bands [19]. The mega companies possess competitive strengths in terms of computing capabilities within their cloud and virtualization infrastructure, which leads to interest conflicts with network operators. Besides, the conflicts between environmental sectors with others primarily arise from differing considerations and perspectives of sustainability issues.

The two dotted lines in Figure 4 show the ambivalent relationships. One of these lines illustrates the ambivalent relationship between the cybersecurity sector and the telecom industry, while the other represents the ambivalent relationship between the infrastructure vendor and the satellite and aerospace industry. These relationships are characterized by mixed dynamics and the potential for both cooperation and conflict. One of the key challenges in the 6G landscape is security and privacy, and cybersecurity firms play a pivotal role in addressing these issues. On the one hand, they can enhance 6G security through cooperation with the telecom industry, contributing to the development of secure 6G networks. On the other hand, they may also pose limitations on 6G development due to security considerations, potentially imposing strict requirements that could hinder the rapid deployment of 6G technologies. 6G extends terrestrial network to non-terrestrial access through low earth orbit satellites [45]. This expansion opens up new opportunities and challenges for both infrastructure vendors and the satellite and aerospace industry. Both sectors have the competitiveness and capabilities to enter the non-terrestrial market. They can choose to cooperate, recognizing the mutual benefits of combining their strengths in this emerging field, or they probably become competitors in the non-terrestrial market.

4.4 Key Opportunities and Challenges

The author of the paper [13] raises a question of whether 6G could be a game-changing technology, just like the 2G transition from analogue to digital. It is a similar question to whether 6G will be a GPT. The increasing role of AI and ML in wireless networks [13] will likely give a positive answer to this question, which offers corresponding opportunities for all stakeholders in the 6G software business ecosystem together with challenges.

6G will not only enhance the network performance but also improve user experience. The papers [35] and [6] also indicate that AI can assist in automating SDN management and decision-making processes, which means 6G resource orchestration will be more efficient without the need for human intervention. As more devices are connected in the 6G era and huge amounts of data are transmitted through the network, privacy and security will be a critical concern, and AI could be used to do real-time detection to ensure network safety [34]. Since 6G under the umbrella of AI improve the overall user experience from multiple aspects and promotes the emergence of more innovative software business use cases [34]. Thus, systematic integration with AI technology from both technical and business perspectives is the key opportunity that needs to be grasped by stakeholders in the 6G software business ecosystem.

In the 6G context, identifying challenges is more crucial than being aware of what the opportunities are due to the following three reasons. Firstly, opportunities are usually easier and more obvious to be realized than challenges. Business practices should not underestimate the significance of addressing challenges. Reducing the possible risk by fully understanding the challenges is equal to or more crucial than grasping opportunities for businesses pursuing long-term development. Secondly, some opportunities can be found in challenges, which further means turning challenges into opportunities through a proactive and innovative approach. From a software business perspective, the greatest opportunities often arise from critical challenges; furthermore, technical challenges always lead to business opportunities. Lastly, opportunities could be more different for various stakeholders during different 6G developing stages. While the challenges are likely to share more common aspects for all participators. In conclusion, we need to pay more attention to the challenges part when considering 6G software business innovation.

Some articles, for example, Ziegler V and Yrjola S's paper [45] said that surpassing 5G intrinsic system specification limits is a challenge for 6G. It is more from the 6G technical capability perspective, while the specific performance factors are not so much concerned from a 6G software business view. In Finland, Hexa-X project [39] formulated both technology advancement and societal values challenges, including connecting intelligence, network of networks, sustainability, global service coverage, extreme experiences, and trustworthiness. Many emerging technologies face the sustainability challenge. A guest post from the 6Gworld website announced that today around 2-3% of global carbon emission is contributed to networks and data centres [12]. Due to the rapidly increasing number of connected devices and data produced by them in the 6G era, the carbon share is predicted to reach 14% in the following two decades. Sustainability of tremendous magnitude is the core challenge when designing a 6G software business [22]. Key drivers and research challenges for 6G ubiquitous wireless intelligence. It has reached a consensus that 6G development should be aligned with the United Nations Global sustainability goals

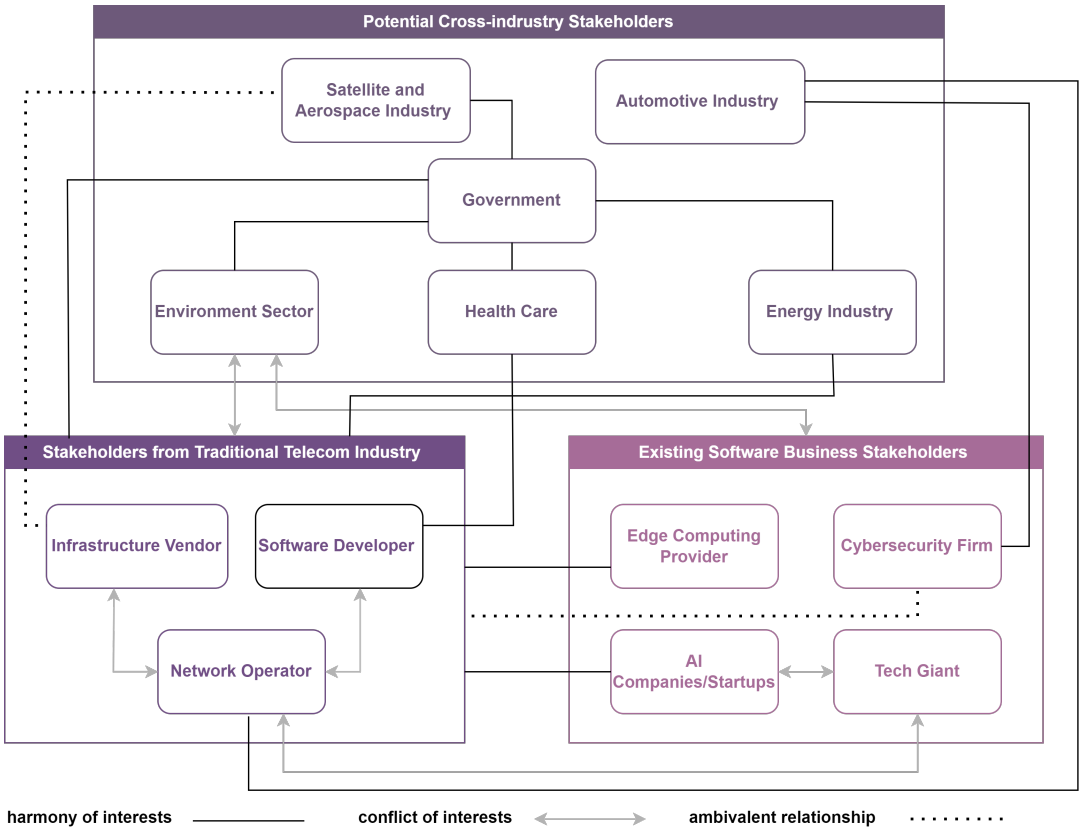

Figure 4. Harmony, conflict, and ambivalent relationships in 6G value network

[22]. Based on that conclusion, the paper [26] emphasizes the importance of reinforcers in a new sustainable ecosystem. Thus, establishing an organic sustainable 6G software business ecosystem is a foundation of sustainable 6G.

New roles along with novel business models will emerge in the 6G ecosystem. 6G indeed open the market for all new stakeholders [26], while the uncertainty of that open ecosystem is a notable challenge. Open 6G software business ecosystem attracts more participators most of them most likely come from software and related industries because the nature of 6G is an SDN. How they will act in the new ecosystem and what the future value chains will look like are full of uncertainty which is another challenge in the 6G business context. Such uncertainty also provides opportunities, especially for the players who first enter or transform their business to the 6G ecosystem. They own the opportunities to participate in the process of shaping the 6G software business ecosystem. Another identified challenge is globalization, which can be also interpreted as digital equity. Digital equity is a concept that each person should be able to access digital technologies, including connecting to the network. Although some countries have already closed the 2G business and fully transitioned to the latest generations, it cannot be ignored that a large number of areas still rely on 2G. Whether the coming 6G will also cover the underdeveloped regions worldwide or only be applied in certain developed regions is still unknown. The conflict between globalization and localism could be more acute in the 6G world. Whether 6G will connect everyone to make the world closer or separate the world in the opposite direction, which refers to localism or nationalization.

5 Conclusion and Future Work

We first address the state-of-art of 6G development and emphasize the critical role of business perspective for 6G commercialization. By introducing the terms software ecosystem and business ecosystem, the rationale of modeling the 6G Software Business Eocoystem is presented. 6G software business transformation and innovation are the key factors for making 6G a real GPT. Regarding the adopted research methodology, this paper mainly generates a systematic way for modeling the 6G software business ecosystem and contributes to applying MA in the software engineering field. Our study mainly adopted MA methodology from the Future Study field, together with literature review and stakeholders analysis approaches from the foresight diamond. We also

followed the guidelines from a five-stage business ecosystem architecture design approach.

Four building blocks are identified for understanding the 6G software business ecosystem, firstly starting with the 6G vision through the lens of software business. A software business-oriented 6G vision is generated in this study based on our previous SLR work. The crucial position of AI and the connectivity of physical, digital, and virtual worlds are emphasized in the proposed vision. The following two building blocks are 6G stakeholders and the complex relationships between their multiple roles. Different from other digital ecosystems, no focal stakeholder orchestrates the 6G software business ecosystem. The central position of MNOs, who are the owners of the past telecommunication ecosystems before 5G, face huge challenges in the 6G era and need to shift their roles. It is important to note that the 6G software business ecosystem is highly dynamic, with constantly shifting stakeholder roles and relationships. The term stakeholder is used in this study to encompass both individuals and organizations that impact the ecosystem without necessarily having direct interactions. In this ecosystem, it is common for a single stakeholder to take on multiple roles at the same time. The relationships between stakeholders are complex since each of them owns several roles simultaneously, and harmony, conflict, and ambivalence are the three identified relationships. When discussing the last building block key opportunities and challenges, the three challenges including sustainability, uncertainty, and digital equity, are more emphasized. Besides, sustainability is addressed in this vision as well as in the last building block when discussing challenges.

In future work, we will publish our SLR work by adding recent publications, evaluating the modeling results of the 6G software business ecosystem, and generalizing the MA methodology for the software engineering field. Firstly, We will select the articles published in the second half of the year 2023 and add the selected ones to our SLR work. Since our previous SLR work only includes papers before July 2023 and a lot of papers emerge after that. Also, since no empirical business practices are available for 6G yet, we are considering including papers focusing on lessons from 5G commercialization in SLR to better understand future 6G business. Secondly, the framework of the 6G software business ecosystem proposed in this paper needs to be evaluated in the real business context by involving industrial participators and stakeholders. It is necessary to understand how the roles of a specific stakeholder from a software-intensive industry, for example, MNOs, will be shifted and transformed in the 6G software business ecosystem. Lastly, we aim to explore the methodologies for future research work in the software engineering field, especially modeling a future business ecosystem. The generalization of modeling method is based on evaluation results and needs an iterative improvement process.

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